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DECENTRALIZED APPLICATION FOR AUTO-INSURANCE INDUSTRY: AN INTERPLANETARY FILE SYSTEM AND BLOCKCHAIN-BASED PARADIGM FOR OPTIMAL DATA AND CLAIM MANAGEMENT

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ABSTRACT

The auto-insurance industry faces significant challenges related to data security, fraud, and inefficiencies due to its centralized structure, reliance on intermediaries, and extensive paperwork. These issues compromise trust and transparency, key elements for effective insurance management. This paper proposes a solution that leverages blockchain technology and the Interplanetary File System (IPFS) to create a decentralized, secure, and transparent platform for managing policy and claim data. The system uses Ethereum-based smart contracts and IPFS to enhance the efficiency and security of auto-insurance processes. A multi-consensus mechanism ensures all stakeholders, including insurers and policyholders, participate equitably in claim approvals and settlements, reducing the need for intermediaries and improving trust.A notable feature is the vehicle lifecycle management module, which securely tracks vehicle data throughout its lifespan, reducing fraud and streamlining processes. The Decentralized Application (DApp) interface allows users to create policies, submit claims, and track their progress in real time, with data securely stored on IPFS to ensure immutability and decentralization.By combining blockchain's consensus and security strengths with IPFS's scalable storage, this solution aims to enhance transparency, reduce fraud, and improve operational efficiency in the auto-insurance industry.

Keywords: Blockchain, Smart contract, auto-insurance industry, decentralization, IPFS.

1. INTRODUCTION

The insurance industry, encompassing sectors like healthcare, automotive, and real estate, has become a multibillion-dollar enterprise. However, traditional methods that involve third parties are becoming outdated, leading to increased risks such as cyberattacks, data fragmentation, and fraud, especially in auto insurance. As the automotive industry embraces technological advancements, there's a growing consensus that these innovations could transform traditional auto insurance into more secure and reliable systems. Blockchain technology, known for its immutability and trustworthiness, is seen as a key tool for enhancing reliability, transparency, and decentralization [1]. This introduction provides an overview of blockchain, discussing its development, architecture, and security considerations, and highlighting its potential to revolutionize trust-based systems and data management.The evolution of blockchain technology, beginning with Bitcoin and expanding into a range of contemporary applications, has introduced key concepts that form the basis of various blockchain frameworks and protocols. This development has been instrumental in transforming industries that rely on transparency, security, and trust. Understanding the architecture of blockchain, which includes consensus mechanisms, data structures, and smart contracts, is essential for evaluating its potential[2]. By examining public, private, and hybrid blockchain models, we can better assess their respective strengths and limitations, leading

to a more comprehensive understanding of blockchain infrastructure.

Inauto insurance industry, the combination of blockchain and the InterPlanetary File System (IPFS)[3] offers promising solutions to longstanding challenges. These technologies address inefficiencies in data management, combat fraud, and enhance transparency. Blockchain's secure, unchangeable ledger paired with IPFS's capability for real-time data access improves transparency and traceability within insurance processes. This combination allows for better monitoring, reduces the likelihood of fraud, and ensures adherence to regulations. Additionally, the integration of smart contracts automates transactions and streamlines record-keeping, boosting operational efficiency and reducing errors.

Auto-insurance sector faces issues like slow response times, lost documents, and the prevalence of fraud. Blockchain technology offers a strong solution by securely managing authentication processes and preventing policy manipulation, thereby reducing the reliance on physical documents and minimizing the risk of data breaches[4]. Research focuses on how blockchain can improve claims management, secure data storage, and enhance fraud detection, ultimately fostering greater transparency and trust among stakeholders. The adoption of a decentralized system using blockchain and IPFS has already shown significant benefits, including enhanced security, cost savings, and better customer experiences, positioning the industry for continued innovation and growth.Blockchain technology is transforming various industries by enhancing security, transparency, and efficiency. In finance, Bitcoin is the first cryptocurrency, enabling digital peer-to-peer transactions, while Ethereum provides a platform for developing smart contracts and decentralized applications. Ripple focuses on secure, low-cost international money transfers, and Stellar facilitates fast, affordable cross-border transactions, especially for the unbanked.In supply chain management, Rechains enhances product traceability and authenticity, IBM Food Trust improves transparency and food safety, and Walton chain combines RFID and blockchain to manage retail supply chain data effectively**[5]**.In healthcare, medical chain enables the secure storage and sharing of medical records, Coral Health enhances the interoperability and security of health data, and Simply Vital Health uses blockchain to improve care coordination and reduce healthcare costs.For voting systems, Voatz offers a mobile voting platform that uses blockchain to ensure election transparency and security, while Follow My Vote provides a system that allows voters to verify their votes independently.In the realm of intellectual property, WIPO uses blockchain to create digital fingerprints of IP assets, providing proof of ownership and preventing unauthorized use. IP Chain offers a decentralized platform for protecting intellectual property rights and facilitating fair licensing**[6]**.

2. Literature Review

Blockchain technology highlights its transformative potential in the auto-insurance industry, particularly within the context of Industry 4.0. Blockchain's decentralized architecture offers significant advantages in terms of security, transparency, and efficiency, particularly in the processing of claims, management of data, and prevention of fraud. However, the adoption of blockchain is not without its challenges. The unregulated nature of cryptocurrencies and the complexities inherent in managing crypto assets pose substantial risks, including market manipulation and fraud[7].

In response to these challenges, the literature emphasizes the need for robust data security measures[8], particularly to protect sensitive customer information from cyber threats. Blockchain's decentralized and immutable nature is identified as a key enabler of trust and transparency in the claims process, reducing the risk of fraudulent activity. Additionally, the shift from traditional manual claims processes to automated, cloud-based systems is highlighted as a means of improving speed and accuracy in claims settlement.The role of stakeholders in the auto-insurance ecosystemincluding clients, law enforcement, insurance companies, banks, and repair centersis also examined. The integration of blockchain technology offers a secure platform for the storage and exchange of critical information**[9]**, enabling stakeholders to streamline operations and enhance trust. The literature discusses the potential of smart contracts to automate and enforce insurance agreements, thereby reducing

administrative overhead and improving the efficiency of claims processing[10].

Despite these advantages, it also addresses the challenges of implementing blockchain technology, particularly in terms of scalability, regulatory compliance, and interoperability. These challenges are compounded by the need to ensure transparency, privacy, and the management of large data volumes within the regulatory frameworks governing the insurance industry.Looking to the future, the background study suggests that blockchain technology could play a significant role in the evolving metaverse**[11]**, particularly in the areas of digital asset ownership and platform interoperability**[**12]. The potential for blockchain to reshape the auto-insurance industry by offering a secure, transparent, and efficient framework for managing payments, claims, and data is evident, but realizing this potential will require continued innovation and research.Thisinspection underscores the importance of addressing the challenges associated with blockchain adoption while highlighting its potential to enhance traceability, control, and security across the auto-insurance industry. As such, the ongoing exploration of blockchain technology is critical to its successful integration and widespread application within the sector[13].It also explores Decentralized Finance (DeFi) by detailing its fundamental technologies, including blockchain, smart contracts, and decentralized applications (DApps)[14]. It covers major DeFi applications, such as lending platforms, decentralized exchanges, yield farming, and stablecoins, emphasizing the benefits of increased transparency and accessibility. The discussion also includes the challenges and risks associated with DeFi, emerging trends like asset tokenization and decentralized autonomous organizations (DAOs)[15], as well as considerations for regulation, risk management, and security. Mainly, it assesses how DeFi might influence the financial sector in the future.

The IPFS-based model aims to address the challenge of increasing blockchain data by enabling more scalable and efficient storage. Instead of storing all data on-chain, which requires every node to maintain a full copy, this model utilizes IPFS for off-chain storage, reducing the storage demands on nodes and improving overall system performance. By incorporating a distributed hash table (DHT) and leveraging the decentralized nature of IPFS, the model enhances blockchain scalability, provides geo-redundancy, and offers a more secure and flexible alternative to centralized storage systems[16].

Consensus mechanisms are vital in blockchain technology for maintaining data integrity, security, and trust in applications like auto insurance. They ensure data immutability by requiring all nodes to agree on transactions, preventing unauthorized changes. These mechanisms enhance transparency, allowing stakeholders to verify transactions and build trust. By decentralizing decision-making, they increase system resilience and reduce the risk of failure. Mainly, consensus mechanisms prevent fraud through cryptographic verification, ensuring secure transactions. They also streamline processes, reduce costs, and strengthen trust between insurers and policyholders[17].

Use case analysis:

Thisexplores various blockchain-based models aimed at transforming the insurance and automotive industries through enhanced transparency, security, and efficiency.The model introduces a blockchain-enabled insurance ecosystem**[18]**that utilizes smart contracts on the Ethereum platform. This system focuses on secure and efficient underwriting, leveraging the Proof-of-Authority (PoA) consensus algorithm to ensure block integrity and transaction security. Within this framework, customers can register, declare policies, make claims, and request refunds, all managed by agents on a private Ethereum network. Smart contracts play a pivotal role in automating processes such as claims and refunds, which enhances transparency and reliability while addressing potential security threats. Additionally, the scalability of the system is analyzed, highlighting the suitability of the PoA algorithm for private blockchain environments.Another study dug into potential applications of blockchain technology within the automotive sector**[19]**. It covers areas such as secure payments, autonomous vehicle charging, prevention of odometer fraud, and vehicle-to-vehicle communication. This approach introduces a blockchain platform designed to track insurance records and prevent fraud, using a permissioned blockchain like Hyperledger. Smart contracts automate various processes, including manufacturer recalls and

insurance payments, thereby improving transparency, data quality, and trust among all stakeholders involved.The CioSy model presents a blockchain-based insurance system designed to remove the need for traditional intermediaries**[20]**. This system utilizes smart contracts to automate key insurance processes, including policy management and claims handling, within a decentralized framework. The system involves several entities, including insurers, insured parties, third-party APIs, and auditors. By managing insurance pools, policies, and claims through smart contracts, the model significantly reduces administrative costs while enhancing transparency and security. Generally, these models illustrate the transformative potential of blockchain technology and smart contracts in revolutionizing the insurance and automotive industries, offering innovative solutions that address specific challenges within these sectors.

Table 1. Comparative Analysis

References	Problem	Solution	Platform	Limitations
Nishara Nizamuddin [2021]	• Lack of trust • Mismanagement of data • Fraudulent transaction	• Blockchain-based IPFS model	• Remix Ethereum-IDE	• Lack of standards • Regulation and Lawusability
Mehmat Demire [2019]	• Scalability • Data privacy and Data security	• Distributed ledger Technology • Blockchain	• Hyper ledger • Permissioned Blockchain	• Data handlingand Transaction fee
Muhammad Nasir Mumtaz Bhutta [2021]	• Blockchain security • Money laundering • Confidentiality	• Blockchain Architecture • Consensus mechanism	• Ethereum • Hyper ledger	–
Abid Hassan [2021]	• Security and Trust issues	• Smart Contracts • Blockchain base framework • PoA(Proof of Authority)	• Ethereum • Private Blockchain	• Generalize for only insurance registration
Faiza Loukil [2021]	• Distributed data storage • Centralized trust issues • Security	• Automation features and Transparent, tamperproof collaborative architecture	• Ethereumblockchain	• Automated payments • Assets transfer • Limit fraud

3.Methodology

The proposed methodology leverages blockchain technology to revolutionize auto insurance claims by using a decentralized ledger to record and track claim data securely. IPFS is integrated for distributed document storage, ensuring efficient access to claim-related files. Blockchain provides a transparent, immutable record of transactions, while smart contracts automate processes like policy issuance, premium calculation, and claim settlement, enhancing efficiency and reducing fraud**[21]**.This approach fosters real-time data verification by stakeholders, improving accountability and reducing costs. It promises to enhance the auto insurance industry's transparency, trust, and operational excellence. Flow related to the transaction process is shown in 'Figure 3.1'system architect.

Transaction Process of Insurance Claim

1.Policyholder request a claim for FIR.
2.Claim accepted issued FIR.
3. Acknowledge FIR by insurance company.
4. Appoint surveyor for the inspection of the vehicle.
5. Inspection complete generate a report.
6. Acknowledge the report by the insurance company.
7. Send transaction approval for payment.
8. Transaction approved; smart contract executed.

9. Store smart contract reports to blockchain and IPFS.

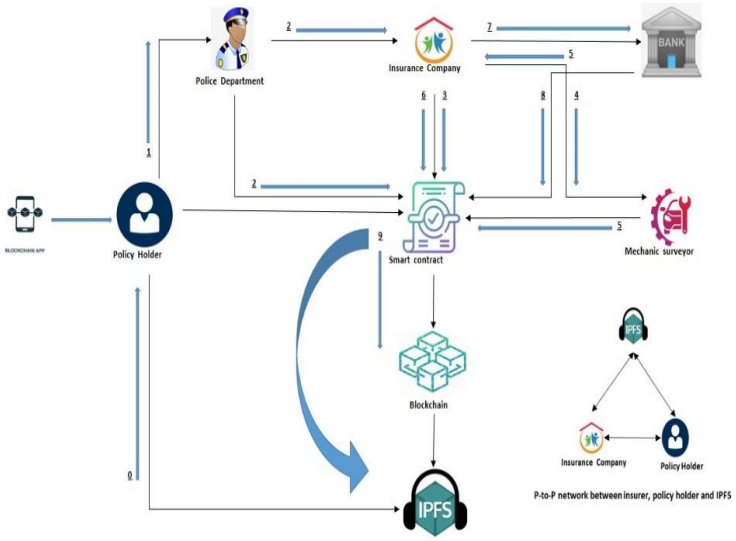


Figure 3.1.System Architect

Insurance Claim Fraud Avoidance

1. Vehicle Registration and Telematics Setup: Vehicle owners register on the blockchain platform and install a telematics device for real-time data collection.

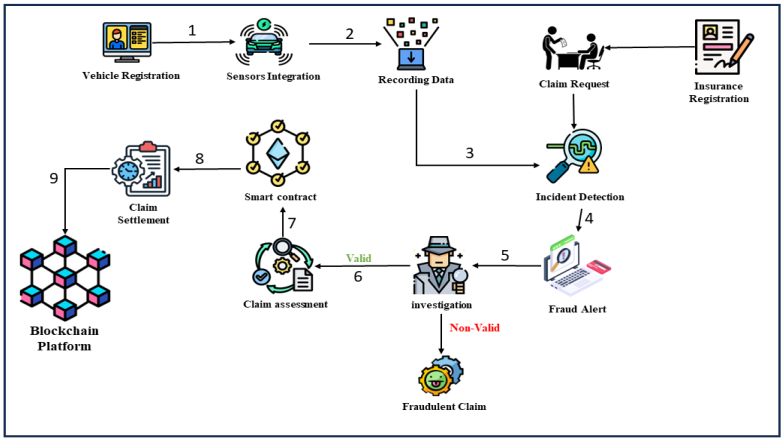
2. Data Encryption and IPFS Storage: Vehicle data is encrypted and securely stored on IPFS (Inter- Planetary File System).

3. Incident Monitoring: Smart contracts continuously monitor data to detect potential incidents or accidents.

4. Fraud Detection: Alerts are triggered if suspicious activity or discrepancies are identified, notifying the insurance company's fraud team.

5. Investigation: The fraud team reviews the incident using encrypted data stored on IPFS and additional data from the telematics device.

8. Settlement: Approved claims are processed, and payments are made through the blockchain network.



6. Claim Evaluation: The validity of the claim is assessed by comparing the recorded data with the reported incident.

7. Automated Claims Processing: Once verified, smart contracts automatically handle claims, including coverage assessment and damage evaluation.

9. Data Integrity and Auditability: All relevant data, including alerts, investigations, and settlements, are permanently recorded on the blockchain, with IPFS links ensuring secure, auditable access to encrypted data.

Figure 3.2:Claim Fraud Avoidance

The collected vehicle data will be securely kept, accessed, and linked to important blockchain transactions by introducing IPFS into the procedure for making transactions visualization of the flow is shown in 'Figure 3.2' claim fraud detection. The integration of IoT [22], blockchain and IPFS technology improves data integrity, security, and accessibility throughout the auto insurance industry's fraud detection and claim evaluation processes**[23]**.

Verification of vehicle by sensors

If the vehicle experiences an incident, the sensors incorporated within it observe and note down any possible details relating to the occurrence. Afterward, this data is utilized to establish what precisely took place. The output deduced from these sensors comes in handy when it comes to decision-making and subsequently generating a forensic report. On top of that, these sensors facilitate vehicle tracking; making sure operations remain optimal for the improvement of driver or occupant experience while triggering relevant alerts for maintenance purposes [24].

Vehicle Record Tracking Using Blockchain and IPFS

When a new vehicle is added to the network, its essential details like VIN, manufacturer, production date, and initial ownership are recorded on the blockchain. This information is securely stored as an immutable transaction, with smart contracts handling updates and management.For large or multimedia data, such as maintenance records and ownership documents, IPFS is used for decentralized storage, ensuring efficient access. Instead of storing entire files on the blockchain, only a hash linking to the IPFS location is recorded, maintaining data integrity and preventing blockchain bloat.Authorized parties, including vehicle owners and manufacturers, access and update records using cryptographic keys, ensuring security and privacy. Any updates, such as repairs or ownership changes, are added to IPFS, with the new hash recorded on the blockchain.Stakeholders

can verify records by cross-referencing IPFS-stored documents with blockchain hashes, ensuring transparency and trust[25]. This approach offers a secure, decentralized, and
efficient system for tracking a vehicle's lifecycle.

Consensus Mechanisms for the Proposed Model

To enhance data and claim management in a blockchain-based auto-insurance system using IPFS, two consensus algorithms are utilized:

Practical Byzantine Fault Tolerance (PBFT) for Initial Stages: PBFT ensures reliability and consistency in permissioned blockchains by using a fixed group of trusted validators. These validators work together to validate transactions through a series of communication rounds, reaching a majority decision. PBFT provides safety by ensuring all nodes agree on transaction order and liveness by maintaining system operation despite faulty nodes.

Proof of Authority (PoA) for Subsequent Stages: PoA is used for efficient transaction validation and block creation in later stages. A select group of pre-approved validators handle transactions and propose blocks, eliminating the need for resource-intensive computations. This approach ensures quick transaction finality and high throughput, relying on the authority of trusted validators to secure the network.

Tools and Techniques

- Blockchain (application).
- Smart contracts (for secure communication).
- Ethereum (for implementation).
- IPFS (for data handling).
- Solidity (programming language).
- Consensus Mechanism (PBFT, POA).

4. Result and Conclusion

Result analysis

The `Auto Insurance` smart contract is structured to manage insurance policies and claims efficiently. It features two primary data types: `Policy` and `Claim`, which handle the details of insurance policies and claims, respectively. The contract utilizes mappings named `policies` and `claims` to connect data with unique identifiers, enabling streamlined data management. Additionally, it tracks the total number of policies and claims using `PolicyCount` and `ClaimCount` counters.The contract includes several events to monitor critical actions. The `Policy Purchased` event is emitted when a policy is acquired, providing the user's wallet address and the policy ID. When a claim is filed, the `Claim Submitted` event is emitted with the claim ID. Once a claim is approved, the `Claim Approved` event is triggered, sharing the ID of the approved claim as shown in the 'Figure 4.1' smart contract deploy.

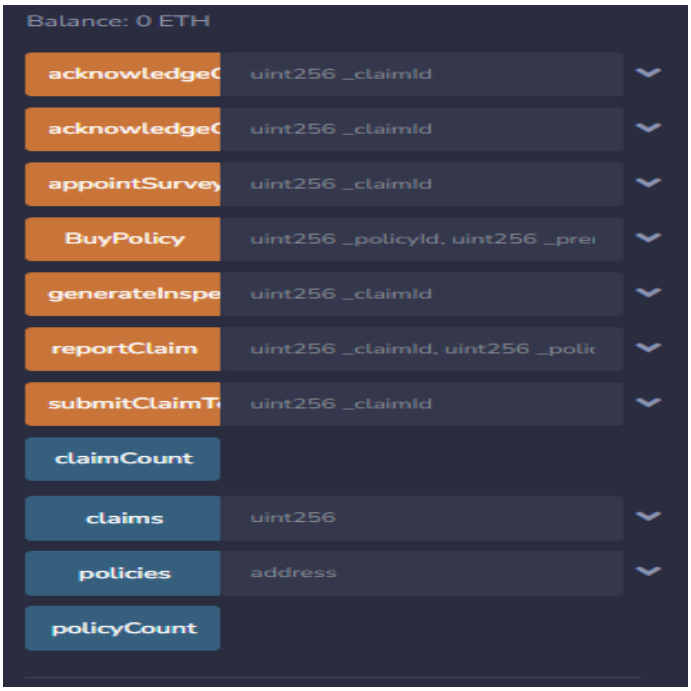


Figure 4.1: Smart Contracts Deploy

For purchasing a policy, users input the policy ID, premium, and deductible. The contract validates these details, adds the policy to the `policies` mapping, updates the `policyCount`, and emits a `Policy Purchased` event. When submitting a claim, users need to provide both the claim ID and policy ID. The contract checks if the user has an active policy, adds the claim to the `claims` mapping, increments the `claimCount`, and emits a `Claim Submitted` event.Claim approval involves verifying the claim ID, ensuring it exists and has not been previously approved, updating its status to approved, and emitting a `Claim Approved` event. The functions `Get Policy` and `Get Claim` allow users to retrieve detailed information about specific policies or claims based on their address or claim ID.

Generally, the contract is designed to facilitate policy purchases, claim submissions, and approvals efficiently, leveraging mappings for data storage and events to communicate significant actions.

Result Outcomes

To create a user-friendly interface for purchasing insurance policies, it's essential to integrate smart contracts that can validate policy details, compute fees, and securely record policy information on the blockchain as shown int 'Figure 4.2' buy policy. This integration should be designed to ensure legal and regulatory transparency, thereby building trust between insurers and policyholders.For claim reporting, a user interface should be developed to enable policyholders to file claims in the event of accidents or damage. Smart contracts will record critical claim details such as the date, time, location, and description directly on the blockchain, ensuring that the claim initiation process is thoroughly documented.

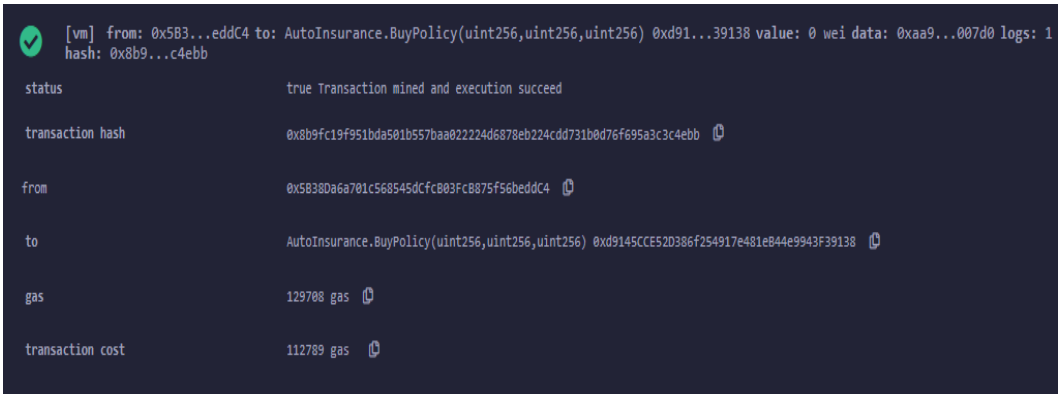


Figure 4.2: Buy Policy

Mechanisms should be established to authenticate First Information Reports (FIRs) submitted to authorities. By utilizing blockchain technology to verify and record these documents, the system can ensure that the billing process is based on validated and accurate information.After a claim is submitted and verified, the smart contract must receive the claim details. This ensures that the subsequent steps in the claim processing workflow are automatically initiated, preserving transparency and data integrity.The smart contract should also provide a verification step for the insurance company to confirm receipt and processing of the claims as shown in **'Figure 4.3'**. This ensures that the policyholder is informed about the progress of their claim.

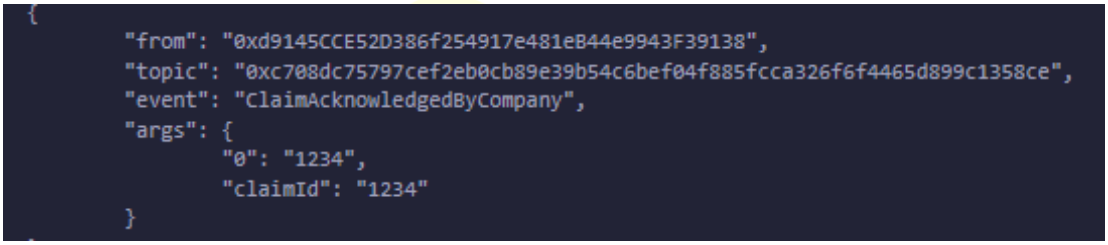


Figure 4.3: Acknowledge the Claim by Insurance Company

Depending on the claim's nature and severity, the smart contract should automatically designate a surveyor to evaluate the damage. Recording these appointments on the blockchain helps maintain transparency and accountability, as illustrated.Finally, the surveyor's damage assessment should be detailed in a report, which is recorded on the blockchain to ensure an immutable record. The insurance company's acknowledgment of this report is a key part of the claims resolution process as shown in 'Figure 4.4'.

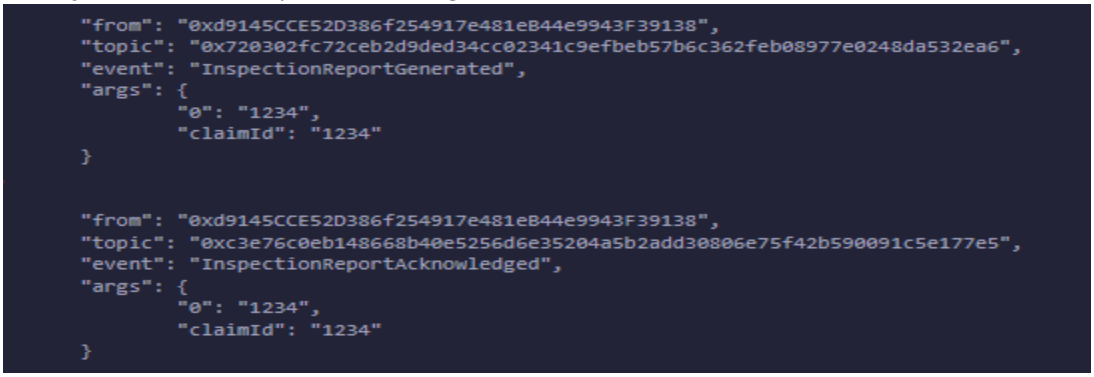


Figure 4.4: Generate and Acknowledge the Claim Report

Conclusion

Our research addresses the significant limitations and challenges that traditional data and claim management systems in the auto-insurance industry face, such as issues with data reliability, confidentiality, and operational efficiency. To overcome these challenges, the study proposes the integration of blockchain technology with the InterPlanetary File System (IPFS). Blockchain offers a decentralized, immutable, and transparent framework that, when combined with IPFS's efficient storage and access capabilities, can significantly enhance data security, streamline claim management processes, and mitigate fraud. This also acknowledges several challenges associated with adopting blockchain in the auto-insurance sector, including scalability issues, integration with existing systems, privacy concerns, regulatory compliance hurdles, technological maturity, and cost considerations. Overcoming these challenges is essential for harnessing the full potential of blockchain and IPFS technologies.

Future research should focus on developing standardized frameworks for integration, improving privacy-enhancing techniques, working with regulatory bodies to create compliant frameworks, and advancing blockchain technology to address current limitations. Additionally, efforts should be made to reduce infrastructure costs, enhance user experience, and decrease the environmental impact of blockchain through energy-efficient consensus mechanisms. At last, while blockchain and IPFS offer promising solutions to current challenges in the auto-insurance industry, their successful adoption will require continuous research, industry collaboration, and technological advancements to overcome existing barriers and fully realize their potential.

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