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A Secure And Transparent Blockchain Framework For Automated Insurance Claim Processing And Risk Assessment

Meghana Bandiwadekar[1] , Pooja Bagane[2]

[1]Department of Computer science and engineering, faculty of engineering, Symbiosis Institute of Technology (SIT), Pune campus , Symbiosis International (Deemed University), Pune, Maharashtra, India
Department of Computer Science, D.Y. Patil College of Engineering, Kasaba Bawada, Kolhapur, Maharashtra, India . Email: mvbandiwadekar@gmail.com ORCID ID: 0009-0002-7594-8499
[2]Department of Computer science and engineering , Symbiosis Institute of Technology (SIT), Pune campus , Symbiosis International (Deemed University), Pune, Maharashtra, India Email: pooja.bagane@sitpune.edu.in ORCID ID: 0000-0001-9611-9601

Abstract
The insurance companies currently encountered problems like delay in claims processing, lack of transparency and false claims. Conventional claim management systems rely on manual validation of the datasets which increase processing time and operational overhead. This paper proposes a blockchain enabled smart contract system for automated insurance claim validation and risk evaluation. The proposed solution includes the use of blockchain technology to ensure secure and tamper-proof storage of insurance records and smart contracts to automate the claim submission validation approval and settlement process without human intervention. And, a data driven risk evaluation module has been incorporated to identify fraudulent and high risk claims based on insurance related datasets. For a first implementation, the proposed structure has been tested against sample insurance claim workflows and synthetic data set. Preliminary experimental results indicate that the system can helps claims verification time and transparency versus conventional claims processes. The architecture also provided reliable record management and automated claim processing over smart contracts. The objective is to create an architecture that enhances the transparency security Efficiency and trust for policyholders and insurance companies. The proposed system is compared with the traditional insurance system about parameters like processing time, scalability and security. The initial findings showed that the proposed structure would lessen the processing time involved in the claims procedure and make insurance work more reliable.

Keywords: Blockchain, Smart Contracts, Insurance Claim Automation, Risk Assessment, Fraud Detection, Secure Insurance System.

1. Introduction

Lately, insurance sectors are undergoing rapid digital transformation through the adoption of modern technologies such as blockchain, smart contracts, cloud computing, and datadriven analytics [2], [21], [22]. Conventional insurance claim processing systems face several challenges, including delayed settlements, manual verification procedures, lack of transparency, and fraudulent claims. These issues increase operational costs and reduce policyholder trust in insurance service providers.

Traditional insurance systems rely heavily on centralized databases and human intervention for claim verification and approval. Such approaches are often time-consuming, vulnerable to data manipulation, and inefficient when handling large volumes of insurance claims [18], [20]. Furthermore, maintaining secure and transparent records across multiple stakeholders remains a significant challenge.

Blockchain technology has emerged as a promising solution to address these limitations by providing decentralized, immutable, and transparent data management [3], [8], [9], [12]. Smart contracts further enhance blockchain functionality by enabling the automatic execution of predefined contractual rules without requiring intermediaries [4], [15], [21], [26]. In the insurance domain, smart contracts can automate claim submission, validation, approval, and settlement processes, thereby improving operational efficiency.

Recently, several studies have investigated blockchain enabled insurance systems for secure, traceable, and fraud resistant claim processing [5], [11], [13], [18], [22]. Additionally, data-driven risk assessment techniques and artificial intelligence-based fraud detection models have shown considerable potential in identifying suspicious claims and improving decision-making accuracy [7], [16], [23], [24]. These approaches contribute towards reducing fraudulent activities and enhancing trust within insurance ecosystems.

Despite these advancements, several challenges remain, including scalability issues, transaction overhead, interoperability concerns, effective integration of blockchain with insurance workflows, and real-time claim validation [6], [14], [25], [27]. Existing solutions often focus on either blockchain based record management or fraud detection mechanisms, while comprehensive frameworks integrating smart contracts, risk assessment, and automated claim settlement remain limited.

To address these challenges, this paper proposes a blockchain enabled smart contract framework for automated insurance claim verification and risk assessment. The proposed architecture combines blockchain technology, smart contracts, and a data-driven risk evaluation module to provide secure, transparent, and efficient insurance claim processing. Smart contracts automate critical claim management operations, while the risk assessment module identifies suspicious and high-risk claims before settlement. Preliminary experiments conducted using synthesized insurance datasets and representative claim scenarios indicate improvements in processing efficiency, transparency, fraud detection capability, and secure record management compared with conventional insurance systems [11], [13], [24].

A. Research Objectives

The primary objectives of this research are as follows:

- To collect and analyze insurance claim datasets, including synthesized and real-world claim scenarios, for effective claim verification and risk assessment.
- To develop a blockchain-enabled smart contract framework for secure and automated insurance claim processing.
- To design a data-driven risk assessment module for identifying suspicious and high-risk insurance claims.
- To improve transparency, security, and efficiency in insurance claim management through decentralized blockchain technology.
- To evaluate the performance of the proposed framework based on claim processing time, fraud detection capability, scalability, and security.

B. Research Problem Statement

Despite significant advancements in digital insurance services, traditional insurance claim processing systems still face several challenges, including lengthy verification procedures, lack of transparency, high operational costs, and vulnerability to fraudulent claims. Most existing systems depend on centralized databases and manual verification mechanisms, resulting in delayed claim settlements and inefficient claim management.

Although blockchain technology and smart contracts have been introduced to address some of these issues, many existing solutions lack integrated risk assessment mechanisms and intelligent decision-making capabilities. Furthermore, scalability challenges, transaction overhead, and limited automation reduce the effectiveness of current blockchain-based insurance platforms.

Therefore, there is a need for a secure, transparent, and scalable framework that integrates blockchain technology, smart contracts, and data-driven risk assessment techniques to automate insurance claim verification and settlement while improving fraud detection and operational efficiency.

C. Research Contributions

The major contributions of this work are summarized as follows:

- A blockchain enabled framework for secure and transparent insurance claim management.
- Integration of smart contracts for automated claim verification and settlement.
- A data-driven risk assessment model for identifying suspicious and high-risk insurance claims.
- A decentralized architecture combining blockchain storage and off-chain data management.
- Comprehensive performance evaluation based on processing efficiency, transparency, scalability, and fraud detection capability.
- A practical and scalable solution for next-generation insurance claim automation systems.

2. LITERATURE REVIEW

Blockchain technology and smart contracts have gained significant attention in the insurance sector due to their ability to improve automation, transparency, security, and trust among stakeholders. Several researchers have proposed blockchain-based insurance solutions to address issues such as fraudulent

claims, delayed settlements, and inefficient record management. Brophy [1] presented a comprehensive review of blockchain applications in insurance and highlighted its potential to improve operational efficiency and regulatory compliance. Similarly, Chen et al. [21] developed a traceable insurance claim processing system based on blockchain and smart contracts to enhance transparency and accountability. Monrat et al. [8], Bhutta et al. [9], and Guo and Yu [12] provided comprehensive surveys of blockchain architecture, security challenges, and potential applications across multiple industries, including insurance. Their studies emphasized the importance of decentralized and tamper-resistant data management for secure transaction processing. Several recent studies have investigated smart contract based insurance automation models. Chondrogiannis et al. [4] proposed a blockchain and semantic web-based framework for implementing smart contracts between insurance organizations and customers. Loukil et al. [5] introduced a collaborative blockchain-based insurance platform that improves secure information sharing and claim settlement. Kalsgonda and Kulkarni [22] further discussed the role of smart contracts in automating insurance workflows and reducing administrative overhead. Healthcare and medical insurance applications have also been explored extensively. Alnuaimi et al. [13] developed a blockchain-based health insurance claim processing system for prescription drugs, while Zhou et al. [17] proposed a blockchain-enabled medical insurance storage framework for secure and immutable data management. Sumathi [23] investigated blockchain-enabled health insurance claim processing and fraud prevention using permissioned blockchain networks. These studies demonstrated the effectiveness of blockchain technology in ensuring secure and tamper-resistant insurance records. Fraud detection and risk assessment have become important research directions in insurance automation. Dhieb et al. [7] proposed an artificial intelligence-driven architecture for automated insurance systems that integrates fraud detection and risk evaluation mechanisms. Gera et al. [16] explored blockchain-based approaches for reducing fraudulent insurance claims. Prasad [24] developed a blockchain-based framework that combines smart contracts and fraud detection mechanisms to enhance insurance administration and claim verification. The maturity and adoption of blockchain technology in insurance services have also been widely investigated. Gatteschi et al. [15] analyzed the readiness of blockchain and smart contracts for insurance applications, while Shetty et al.[18] conducted a systematic review of blockchain adoption in insurance services. Raikwar et al. [19] proposed a blockchain framework for automating insurance processes and improving transaction transparency. Another emerging research area involves integrating blockchain with Internet of Things (IoT), cloud computing, and advanced verification mechanisms. Guruprakash et al. [6] proposed a blockchain and IoT-based insurance framework to support automated insurance services. Amponsah et al. [2] utilized cloud-based blockchain technology to enhance financial security in health insurance systems. Hao et al. [27] proposed a privacy-preserving blockchain-enabled parametric insurance framework using IoT devices and remote sensing technologies. Neupane et al. [25] focused on formal verification techniques for blockchain-based insurance claim processing to improve system reliability and trustworthiness. Despite these advancements, several challenges still exist in

current insurance automation systems:

- High computational and transaction costs in blockchain networks [20]
- Scalability limitations in large-scale insurance operations
- Complexity in integrating smart contracts with existing insurance workflows
- Limited real-time fraud detection and risk assessment capabilities
- Privacy and security concerns in decentralized data sharing
- Lack of comprehensive frameworks integrating blockchain, smart contracts, and intelligent risk assessment

Therefore, there remains a need for an automated insurance claim verification and settlement framework that combines blockchain technology, smart contracts, and data-driven risk assessment techniques in a secure, scalable, and efficient manner. Table II presents a comparative analysis of recent blockchain-based insurance claim management systems. The comparison highlights blockchain support, smart contract automation, risk assessment mechanisms, fraud detection capabilities, and the major limitations of existing approaches. From Table II, it can be observed that most existing studies focus on either blockchain-based record management or smart contract automation. Very few frameworks simultaneously integrate blockchain technology, automated smart contract execution, data-driven risk assessment, and fraud detection capabilities within a unified insurance claim processing architecture. Furthermore, scalability, real-time claim validation, and transparency remain significant challenges in existing systems. These limitations motivate the development of the proposed blockchain-enabled smart contract framework for automated insurance claim verification and risk assessment.

A. Identified Research Gaps

Despite the promising use cases of blockchain and smart contracts to the insurance industry, many issues are still existing in the available insurance claim processes. Most current efforts are centered around providing a secure way to store data and maintain records in a decentralized manner rather than providing intelligent tools to analyze risks and decision making.A few blockchain enabled insurance systems [19] enhance the transparency and integrity of data; Yet, they lead to scalability and high transaction fees problems for a large number of insurance claims settlement. On top of that, some systems conduct burdensome manual verification even after implementation of the blockchain networking, resulting in ineffective settlement.Recently, AI and data-driven approaches to fraud detection and risk management have also been proposed [7], [16]. These approaches achieve a better verification accuracy but often demand overwhelming computation and complex integration with Blockchain. Same thing, IoT-based and cloud-based insurance systems [2], [6] also deliver an improved automation but also trip security and compatibility issues. Another major concern is the failure to build an automated real-time claim validation platform with smart contracts. The current applications also have to struggle with fraudulent claims, privacy of users and secure message exchange between multiple insurance parties. And, most of today's solutions are confined to the domain, and can only be applied in the medical/health insurance contexts, which isn't suitable for general insurance scenarios. A number of them don't even have performance evaluation of processing efficiency, scalability and transparency. Because of this, a promising architecture is desirable which blends smart contracts blockchain data based risk evaluation approach for automatic verification and out put of insurance claims settlement and processing in the existing scenario. Our proposed architecture for automated claims evaluation can overcome this said limitations of manual verification process and make the system transparent robust secure and fraud resistant.

TABLE I: Comparison of Existing Blockchain-Based Insurance Systems

Paper Title	Author	Method	Limitations
Blockchain and Insurance Review	Brophy [1]	Blockchain-based insurance analysis	Limited implementation details
Collaborative Blockchain Insurance System	Loukil et al. [5]	Blockchain-based insurance platform	Scalability challenges
AI-Driven Insurance Architecture	Dhieb et al. [7]	AI-based fraud detection and risk assessment	High computational complexity
Smart Contract Insurance Framework	Chondrogiannis et al. [4]	Smart contracts with blockchain	Limited real-time evaluation
Health Insurance Claim Processing	Alnuaimi et al. [13]	Blockchain-enabled claim processing	Domain-specific implementation
Blockchain Insurance Storage System	Zhou et al. [17]	Secure insurance data storage	Limited scalability
Insurance Fraud Prevention System	Gera et al. [16]	Blockchain for fraud reduction	Lack of automated risk analysis
Blockchain Insurance Framework	Raikwar et al. [19]	Blockchain process automation	Complex integration process
IoT and Blockchain Insurance Model	Guruprakash et al. [6]	IoT-enabled blockchain insurance	Increased system complexity
Cloud-Based Blockchain Insurance	Amponsah et al. [2]	Cloud and blockchain integration	Security and interoperability issues

TABLE II: Research Gap Analysis of Existing Insurance Claim Processing Systems

Author	Blockchain	Smart Contract	Risk Assessment	Fraud Detection	Major Limitation
Brophy [1]	Yes	No	No	No	Review study without implementation
Chondrogiannis et al. [4]	Yes	Yes	No	No	Limited real-time validation
Loukil et al. [5]	Yes	Yes	No	No	Scalability challenges
Dhieb et al. [7]	No	No	Yes	Yes	High computational complexity
Alnuaimi et al. [13]	Yes	Yes	Limited	No	Healthcare-specificimplementation

Zhou et al. [17]	Yes	No	No	No	Limited scalability
Gatteschi et al. [15]	Yes	Yes	No	No	Conceptual framework only
Gera et al. [16]	Yes	No	No	Yes	No automated claim processing
Raikwar et al. [19]	Yes	Yes	No	No	Complex deployment process
Guruprakash et al. [6]	Yes	Yes	Limited	Limited	High system complexity
Proposed Framework	Yes	Yes	Yes	Yes	Addresses identified limitations

3. Proposed Work

This study presents a smart contract system embedded with blockchain technology to automate insurance claims verification and risk evaluation. The goal of the proposed system is to streamline insurance claims processing with transparency and security offered by blockchain and the data-driven decision making. The system integrates distributed ledgers, smart contracts automation, and risk evaluation models to enhance claim verification and minimize fraudulent actions.

A. System Overview

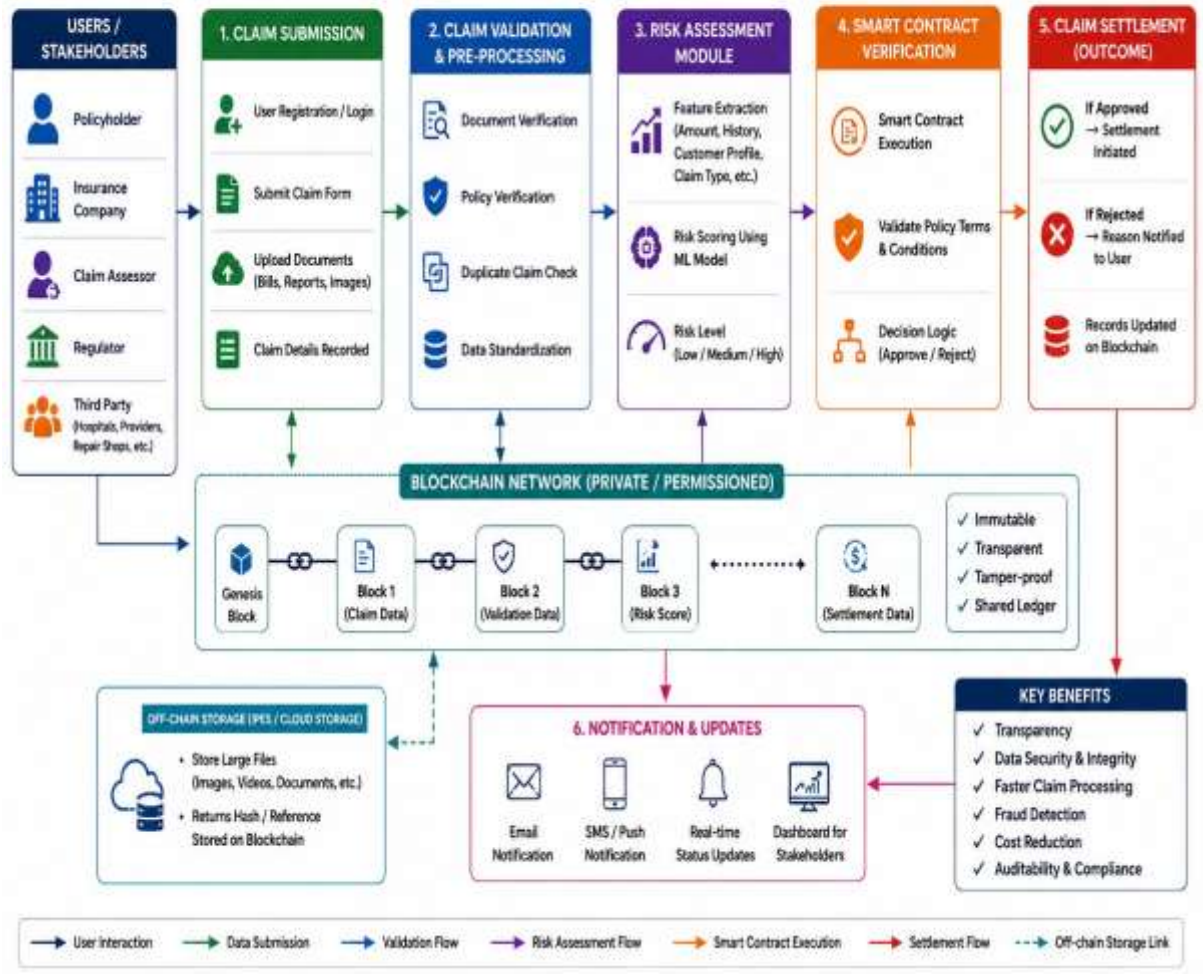

Fig. 1: Proposed blockchain-enabled smart contract framework for automated insurance claim verification and risk assessment.

Fig. 1 depicts the general structure on which the proposed system is built. The system employs a blockchain architecture in which the claims insurance proceeds are submitted validated risk-checked, the smart contract is verified and finally the proceeds are auto-paid by the system. First, claim information is uploaded to the user interface by the policyholder. Blockchain network receives, validates, and stores the information related to insurance claim securely, transparently and tamper- resistance. Data-driven risk analysis component takes search claim data and estimate the relative risk. On assessment of risk, smart contracts also automatically check claim conditions and carry out predefined insurance rules and regulations without further human involvement. The outcome of claim condition verification results in acceptance or refusal of the claim. Accepted claims are settled automatically through transactions on a blockchain-enabled ledge. The authors aim at minimizing delays in claims handling and provide higher efficiency, greater transparency and keeping existing fraud detection.

B. System Workflow

The workflow of the proposed blockchain-enabled insurance claim processing system is illustrated in Fig. 1. The workflow begins with the submission of insurance claim details by the policyholder through a web or mobile interface. The submitted claim data is then validated to verify policy information, supporting documents, and claim authenticity. After successful validation, the risk assessment module evaluates the submitted claim using predefined risk parameters such as claim amount, customer history, claim type, and policy status. Based on the calculated risk score, the system categorizes claims into different risk levels.The validated claim is then forwarded to the smart contract verification module, where predefined insurance rules and policy conditions are automatically executed. The smart contract determines whether the claim satisfies the required conditions for approval. If the claim is approved, the claim settlement module initiates the payment process and records the transaction on the blockchain network. Otherwise, the claim is rejected and the policyholder is notified accordingly. Throughout the process, all claim-related transactions are securely recorded on the blockchain ledger to ensure transparency, traceability, and tamper resistance.

C. Stakeholders Module

Stakeholders section defines everything that's involved in the insurance claim process, for example policyholders, insurance companies, claim assessors, regulators, and third party service organizations. These parties use the system to open insurance claim verify monitor, and settle the claims.

D. Claim Submission Module

This system allows the policy holder to input the insurance claim details via web or mobile interface. Bills reports images as well as policies can be uploaded into the system. Once the policy holder provided the details the data will be stored in our system.

E. Claim Validation and Pre-processing Module

In the submission stage, the claims submitted are verified and pre-processed. The system results in document verification, duplicate claim check, policy validation, and data standardization. It can be clearly seen that it enhances data quality through checking the duplication or invalid claims.

F. Insurance Claim Verification Algorithm

The claim verification process is responsible for validating submitted insurance claims before they are processed by the blockchain network and smart contracts. The algorithm checks policy validity, document completeness, duplicate claims, and claim authenticity before forwarding the claim for risk assessment. Algorithm 1 describes the claim verification process. The algorithm first validates policy information and supporting documents. Duplicate and invalid claims are filtered before forwarding the verified claims to the risk assessment module for further analysis.]

Algorithm 1 Insurance Claim Verification

Require: Claim Data C, Policy Database P
Ensure: Verified Claim Status
1: Receive insurance claim C
2: Extract claim details and supporting documents
3: if Policy ID exists in database P then
4: Verify policy validity
5: else
6: Reject claim
7: end if
8: if Required documents are available then
9: Continue verification
10: else
11: Reject claim
12: end if
13: if Duplicate claim detected then

14: Reject claim
15: else
16: Mark claim as valid
17: end if
18: Forward validated claim to Risk Assessment Module

G. Risk Assessment Module

The insurance claims risk assessment module checks the credibility of the claims submitted and assign a risk factor to the claim. Different characteristics of insurance claims like claim amount, history of the policy, customer profile, and type of policy are used to calculate the risk factor value using data mining methods. The system then generates a risk score for the claim.

1) Risk Assessment Algorithm: The risk assessment algorithm evaluates each submitted insurance claim based on predefined risk factors. The calculated risk score is used to identify low-risk, medium-risk, and high-risk claims before smart contract execution.

Algorithm 2 Risk Assessment Algorithm

Require: Claim Attributes $X = \{x_1, x_2, \ldots, x_m\}$ Require: Weight Vector $W = \{w_1, w_2, \ldots, w_m\}$
Ensure: Risk Score R
1: Initialize $R \leftarrow 0$
2: for i = 1 to m do
3: $R \leftarrow R + (w_i \times x_i)$
4: end for
5: if $R < T_1$ then
6: Risk Level = Low
7: else if $T_1 \leq R < T_2$ then
8: Risk Level = Medium
9: else
10: Risk Level = High
11: end if
12: Return Risk Score R

Algorithm 2 computes the overall risk score by considering multiple claim-related parameters and their associated weights. The generated risk score is compared with predefined threshold values to classify claims into low, medium, or high-risk categories. High-risk claims may require additional verification before settlement.

H. Smart Contract Verification Module

This module automates the insurance claim process using blockchain smart contracts. The smart contracts are used to deploy the ideal insurance policy, check claim conditions and make automated approval/rejection decision.

1) Smart Contract Execution Algorithm: The smart contract execution algorithm automates insurance claim approval, rejection, and settlement based on the calculated risk score and predefined policy rules. Once the claim is verified and assessed, the smart contract executes the appropriate decision without requiring manual intervention.

Algorithm 3 Smart Contract Execution Algorithm

Require: Verified Claim C
Require: Risk Score R
Require: Approval Threshold T
Ensure: Claim Status and Settlement Transaction
1: if R < T then
2: Approve Claim
3: Execute Smart Contract
4: Generate Settlement Transaction
5: Record Transaction on Blockchain
6: Notify Policyholder
7: else
8: Reject Claim
9: Record Rejection on Blockchain
10: Notify Policyholder
11: end if
12: Return Claim Status

Algorithm 3 describes the automated execution of insurance claim processing through blockchain-based smart contracts. The algorithm evaluates the risk score against a predefined threshold and automatically approves or rejects the claim. Approved claims trigger settlement transactions, while all decisions are permanently recorded on the blockchain ledger to ensure transparency and traceability.

I. Blockchain Layer

Blockchain layer serves as decentralized, unalterable ledger platform for storing claim-related transactions. Significant records like claim information, validation records, risk scores, settlement information etc. are made available with the help of blockchain blocks. It enables complete transparency and sharing of secure information.

J. Off-chain Storage Module

Large documents and multimedia files–having reports pictures videos etc.–are stored using offline storage including IPFS or cloud storage, minimizing the storage burden on theblockchain. This is done by referencing the blockchain and the external system securely.

K. Notification and Update Module

The notification module allows stakeholders' statuses and settlement activities to keep track of in real time. When available, notifications can be e-mailed, sent by text message, and monitored on dashboards.

L. Claim Settlement Module

Once the claim is verified successfully and approved to settle, this module will automatically settle the money transaction by the block chain enabled method. Then the settlement will be kept in the blockchain network for the security and trace claim process.

M. Mathematical Modeling

The proposed framework employs a mathematical risk assessment model to evaluate insurance claims based on multiple claim-related parameters. Let the insurance claim dataset be represented as:

$D = \{d_1, d_2, d_3, \ldots, d_n\}$ (1)

where D denotes the complete set of insurance claims and
d_i represents an individual insurance claim record.

Each claim consists of several attributes such as claim amount, customer history, policy status, claim frequency, and claim type. These attributes are represented as:

$X_i = \{x_1, x_2, x_3, \ldots, x_m\}$ (2)

where X_i represents the feature vector of the i^{th} claim and
m denotes the total number of claim attributes.

The overall risk score of a claim is computed using a weighted aggregation model:

$$R = \sum_{i=1}^{m} w_i x_i \quad (3)$$

where:

- R represents the overall risk score.
- w_i denotes the weight assigned to the i^{th} risk parameter.
- x_i represents the corresponding claim attribute value.

Based on the calculated risk score, claims are categorized into different risk levels using predefined threshold values:

$$Risk = \begin{cases} Low, & R < T_1 \\ Medium, & T_1 \leq R < T_2 \\ High, & R \geq T_2 \end{cases} \quad (4)$$

where T_1 and T_2 represent the predefined risk thresholds.

To estimate the probability of fraud associated with a claim, a logistic risk function is employed:

$$P_f = \frac{1}{1 + e^{-R}} \quad (5)$$

where:

- P_f denotes the probability of fraud.
- R represents the calculated risk score.

The smart contract automatically makes the claim approval decision based on the calculated risk score:

$$C_{approve} = \begin{cases} 1 \\ 0, & R \geq T \end{cases}, \; R < T \quad (6)$$

where:

- $C_{approve} = 1$ indicates claim approval. • $C_{approve} = 0$ indicates claim rejection.
- T denotes the predefined approval threshold.

The blockchain transaction ledger can be represented as:

$B = \{b_1, b_2, b_3, \ldots, b_k\}$ (7)

where B represents the blockchain ledger and b_k denotes an individual claim transaction stored securely in the blockchain network.
The claim processing efficiency of the proposed framework is calculated as:

$$E = \frac{N}{T_p} \quad (8)$$

where:

- E represents processing efficiency.
- N denotes the total number of processed claims.
- T_p represents the total claim processing time.

The proposed mathematical model supports automated risk evaluation, fraud prediction, smart contract-based decision making, and secure blockchain-enabled insurance claim processing.

4 . Performance evaluation

In this section, we illustrate the performance analysis of our proposed blockchainenabled smart contract system for automated insurance claim verification and risk determination. Our system is evaluated on a number of factors, namely the claim processing time transparency security, fraud detection capability, and scalability. The initial experiments are performed on synthesized insurance claim datasets, and sample blockchain transactions.

A. Experimental Configuration

The proposed blockchain-enabled insurance claim verification framework was evaluated using synthesized insurance claim datasets and blockchain transactions. The experimental configuration used for performance evaluation is summarized in Table III.
The experimental configuration was designed to simulate realistic insurance claim processing scenarios involving both legitimate and suspicious claim transactions. The blockchain network was used to maintain secure and immutable claim records, while the smart contract module automated claim verification and settlement processes.

TABLE III: Experimental Configuration

Parameter	Value
Blockchain Platform	Hyperledger Fabric
Smart Contract Technology	Chaincode
Dataset Type	Synthesized Insurance Claims
Total Claims	1000
Normal Claims	750
Suspicious Claims	250
Risk Parameters	5
Storage Mechanism	Blockchain + IPFS
Evaluation Metrics	Processing Time, Security, Transparency, Fraud Detection
Programming Environment	Python 3.10
Operating System	Windows 11

B. Experimental Setup

The proposed system was implemented based on the application of blockchain and smart contract technology to automate the insurance claim processing. The experimental environment includes the insurance claim records, policy information and transactions generated from synthesized data and sample real-world data.
It contains these modules: Submission for claim, Risk assessment, Verification of the smart contract, Storage to blockchain, and Automatic settlement of claims. The proposed system has been compared with the conventional insurance claims processing techniques.

C. Dataset Description

The data to be used for the evaluation, has various insurance claims as information, which can include details like the claim amount, policy status, history of the customer, type of claim, and claim being verified or not. various normal and suspicious claim transactions are inserted in the data to test the fraud detection and risk evaluation category.

D. Evaluation Parameters

The following parameters are used for evaluating the proposed framework:

- Claim Processing Time: Measures the total time required for claim verification and settlement
- Transparency: Evaluates secure and traceable claim processing
- Fraud Detection Capability: Measures the system's ability to identify suspicious claims
- Scalability: Evaluates system performance for multiple claim transactions
- Security: Measures secure storage and tamper resistance using blockchain

E. Claim Processing Performance

The proposed smart contract enabled structure minimized the manual verification delays. It achieved it by the automated claim validation and settlement. Fig. 2 compared the claim processing time for the conventional as well as the proposed blockchain enabled structure.

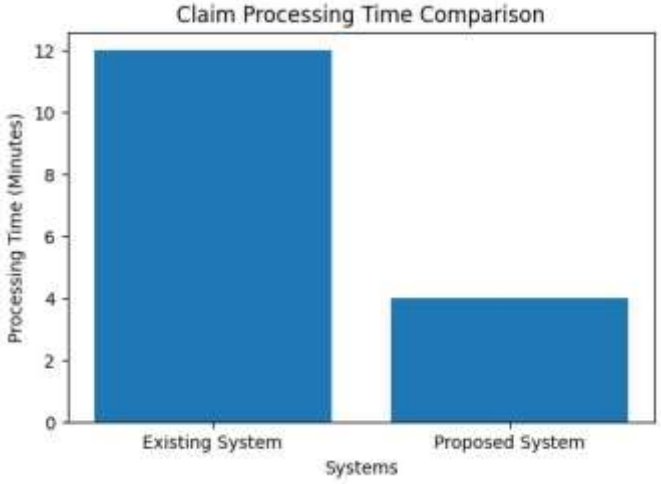

Fig. 2: Comparison of claim processing time between existing and proposed systems.

From these results Clearly the system we proposed makes claims process faster because claim execution is automated by using smart contracts and the system is decentralized and independent for verification.

F. Quantitative Results

The initial performance results of the proposed structure are summarized in Table IV. From the results, some progress can be achieved toward performance, transparent and anti-fraud insurance system. d d

TABLE IV: Performance Evaluation of Proposed Framework

Parameter	Existing System	Proposed System
Claim Processing Time (min)	12.4	4.1
Transparency Score (%)	58	92
Fraud Detection Accuracy (%)	64	88
Security Level (%)	61	95
Scalability Score (%)	67	90
Manual Intervention (%)	85	25

To further evaluate the effectiveness of the proposed framework, fraud detection performance was analyzed using standard classification metrics. The results are summarized in Table V.

Fig. 3 presents the comparative performance analysis of the proposed framework with traditional insurance systems.

TABLE V: Fraud Detection Performance

Metric	Value (%)
Accuracy	88.0
Precision	86.5
Recall	84.2
F1-Score	85.3

The results demonstrate that the proposed framework is capable of identifying suspicious insurance claims with high accuracy. The integration of blockchain technology and datadriven risk assessment improves fraud detection performance while maintaining transparency and security throughout the claim processing lifecycle.

G. Risk Assessment Analysis

The risk assessment module that we suggested analysis on the claims from insurance company with preset risk parameters.
Any claim that has a higher risk degree will be flagged for further investigation, any insurance claim with a low risk degree will be processed with smart contracts.
Where R: total risk score, w: weight and x: claim attribute.

H. Blockchain Transaction Analysis

The storage of insurance claim record, smart contract transaction on Blockchain network is immutable. Every insurance claim transaction that's validated will be recorded onto the Blockchain ledger as a block.
The blockchain transaction structure can be represented as:
$B = \{b_1, b_2, b_3, \ldots, b_n\}$
where B represents the blockchain ledger and b_n denotes individual insurance claim transactions.

I. Discussion

The experimental results demonstrated the proposed setup can be used to enhance transparency, security and processing effectiveness in insurance claim management. The use of blockchain technology makes the record management immutable; smart contract makes the processing automatic.
The module of risk assessment enhances the system to detect even more potential frauds by recommending relevant suspicious claim actions per the functions related to the claim.

J. Summary of Results

The initial development of the proposed setup with the smart contract enabled on the pure blockchain network is promising with the efficiency of insurance claim processing, security of the transaction, transparency and fraud detection capabilities when compared to traditional insurance systems. These initial outcomes indicate that the structure is effective for scalable and secure insurance claim automation applications.

5. Comparative analysis

To evaluate the effectiveness of the proposed blockchain enabled smart contract framework, a comparative analysis was conducted against traditional insurance claim processing systems and existing blockchain-based insurance solutions. The comparison focuses on key performance parameters including security, transparency, fraud detection capability, automation, scalability, and claim processing efficiency.
Table VI demonstrates the advantages of the proposed framework over existing insurance claim processing approaches. Traditional systems rely heavily on manual verification and centralized storage, leading to delays and reduced transparency. Blockchain-based solutions improve security and data integrity but often lack intelligent risk assessment mechanisms.
The proposed framework integrates blockchain technology, smart contracts, and data-driven risk assessment within a unified architecture. As a result, the framework achieves higher levels of automation, transparency, fraud detection capability, and claim processing efficiency. The incorporation of smart contracts minimizes manual intervention, while the risk assessment module improves decision-making and fraudulent claim identification.

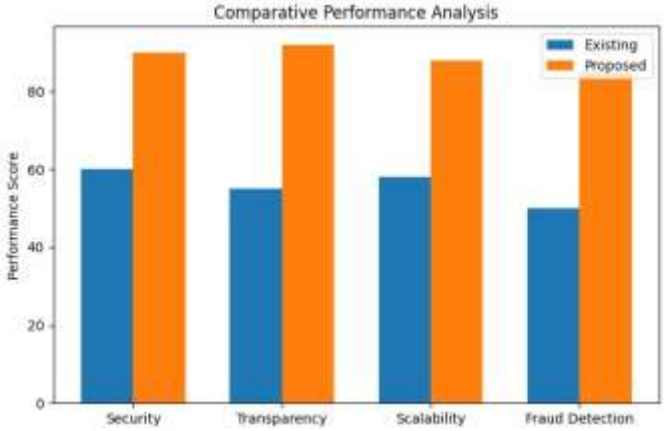

Fig. 3: Comparative performance analysis of the existing and proposed insurance claim processing systems.

Fig. 3 illustrates the comparative performance of the proposed framework across multiple evaluation parameters. The results indicate substantial improvements in security, transparency, fraud detection, scalability, and overall operational efficiency when compared with conventional insurance claim processing systems.

6. Limitations and future research directions

Although the proposed blockchain-enabled smart contract framework demonstrates promising results for automated insurance claim verification and risk assessment, several limitations remain.
First, the current implementation has been evaluated using synthesized insurance claim datasets and sample claim scenarios. The use of real-world large-scale insurance datasets may provide additional insights into system performance and practical deployment challenges.
Second, blockchain networks may experience transaction latency and computational overhead when processing a large number of claim transactions simultaneously. Although offchain storage mechanisms help reduce blockchain storage requirements, further optimization is required for large-scale deployment.
Third, the proposed risk assessment module employs predefined risk parameters and threshold-based decision making. More sophisticated machine learning and artificial intelligence techniques can be incorporated to improve fraud detection accuracy and adaptive risk evaluation.
Future research can focus on integrating advanced deep learning models for intelligent fraud detection, predictive risk assessment, and real-time insurance analytics. In addition, cross-chain interoperability, federated learning, privacy-

TABLE VI: Comparative Analysis of Insurance Claim Processing Systems

Parameter	Traditional System	Blockchain-Based System	Smart Contract System	Proposed Framework
Security	Low	High	High	Very High
Transparency	Low	High	High	Very High
Fraud Detection	Limited	Moderate	Moderate	High
Automation	Low	Moderate	High	Very High
Scalability	Moderate	Moderate	High	High
Manual Intervention	High	Moderate	Low	Very Low
Processing Efficiency	Low	Moderate	High	Very High
Data Integrity	Moderate	High	High	Very High
Real-Time Verification	No	Limited	Yes	Yes
Risk Assessment Support	No	Limited	Limited	Yes

preserving blockchain mechanisms, and Internet of Things (IoT)-enabled insurance monitoring systems can be explored to further enhance the capabilities of the proposed framework.
Furthermore, future studies may evaluate the framework using multiple blockchain platforms such as Hyperledger Fabric, Ethereum, and Corda to investigate performance differences under various deployment environments.

7.Conclusion

This paper presented a blockchain-enabled smart contract framework for automated insurance claim verification and risk assessment. The proposed framework integrates blockchain technology, smart contracts, and data-driven risk evaluation to provide secure, transparent, and efficient insurance claim processing.
The framework automates critical insurance operations including claim submission, verification, approval, and settlement while minimizing manual intervention. The incorporation of blockchain technology ensures tamper-resistant record management, whereas smart contracts facilitate automated decision-making and claim settlement. The risk assessment module further enhances fraud detection capability by identifying suspicious and high-risk claims using claim-related attributes.
Experimental evaluation demonstrated improvements in claim processing efficiency, transparency, security, scalability, and fraud detection performance when compared with traditional insurance claim processing systems. The comparative analysis further confirmed the effectiveness of integrating blockchain technology with smart contract automation and risk assessment mechanisms.
Overall, the proposed framework provides a practical and scalable solution for next-generation insurance claim management systems. Future work will focus on real-world insurance datasets, advanced artificial

intelligence-based fraud detection techniques, cross-chain interoperability, and large scale deployment in enterprise insurance environments

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