PureChain-Secured Behavior-Based Insurance for Internet of Vehicles

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***Abstract*—Behaviour-based insurance (BBI) leverages IoV driving data for personalised policies but faces trust and integrity challenges in centralised models. This paper presents a blockchain-enabled BBI framework on PureChain with Proof-of-Authority and Association (PoA^2) consensus, integrating IoV devices, secure aggregation, a permissioned ledger, and smart contracts for dynamic policy and premium management. Experiments on vehicle telemetry demonstrate PureChain's efficiency with high throughput, tamper-resistant claims, and ultra-low latency of 0.2 s, confirming its suitability for real-time IoV insurance.**

***Index Terms*—Behavior-Based Insurance, Internet of Vehicles, PureChain, PoA^2, Smart Contracts.**

I. Introduction

The expansion of the Internet of Vehicles (IoV) has enabled insurance models that dynamically adjust premiums based on driver behaviour, increasing fairness by rewarding safer driving [1]. Behaviour-Based Insurance (BBI) relies heavily on reliable real-time telemetry data. However, centralised architectures introduce single points of failure, and their data is prone to manipulation and a lack of transparency [2][3].

Blockchain technology offers a decentralised ledger with immutable data records and automated contract execution, addressing these concerns [4][5]. PureChain's PoA^2 consensus, featuring multiple trusted validators, provides high throughput and fault tolerance, which is critical for latency-sensitive IoV use cases [6]. The main contributions of our work are:

1) We develop a secure driving-risk scoring mechanism that incentivizes safe driving by linking rewards and penalties directly to insurance premium adjustments.
2) We design a decentralized insurance framework on PureChain using PoA^{2}consensus, ensuring transparency, scalability, and tamper-resistant policy execution.

II. Proposed Architecture

The proposed system model integrates real-time Internet of Vehicles (IoV) telemetry with a permissioned blockchain to deliver transparent, secure, and dynamic behaviour-based insurance. Vehicle sensors and driver interfaces capture parameters such as speed, acceleration, and driving events, which are processed by an off-chain aggregator to compute behaviour scores while safeguarding sensitive personal data. Summarized results are stored on the PureChain blockchain, where the PoA^2 consensus ensures rapid validation, immutability, and scalability. Smart contracts deployed on the ledger automate policy rules, dynamically adjust premiums based on risk scores, and process claims transparently. Finally, an insurer dashboard and integrated payment gateway provide stakeholders with a secure interface to manage policies, premiums, and claims efficiently.

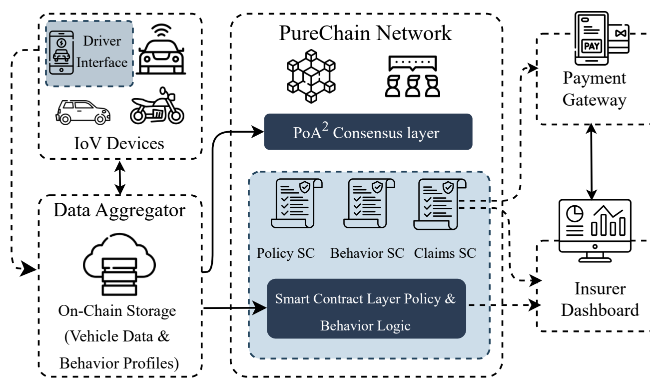

Fig. 1. PureChain-Enabled Behavior-Based Insurance System Architecture for IoV.

Telemetry flows from IoV devices to the data aggregator before critical summaries are committed to the PureChain blockchain. The PoA^2 consensus ensures transaction throughput and fault tolerance essential for real-time responsiveness. Smart contracts execute policy logic autonomously, incentivising safer driving via dynamic premiums and expediting claim settlements with fraud resistance.This modular system model balances scalability, data integrity, privacy, and operational transparency for next-generation IoV insurance solutions.

III. Simulation-Based Analysis

The prototype leverages telemetry data, including vehicle speed, accident on-site, engine, driver's heart rate, and other parameters [7], which is preprocessed and used machine learning algorithm to generate behavioural risk scores. These scores feed Solidity contracts deployed on PureChain's PoA^2 validators. The system integrates policy management and payment via Web3 APIs, ensuring secure interactions with insurer dashboards.

A. Risk Score Calculation

Driver risk was quantified using a weighted normalised aggregation method. Features (accident-onsite, heart rate, and speed) were normalized with min–max scaling, and combined as

$$R = \sum_{i=1}^{n} w_i \cdot f_i^{\text{norm}}, \quad w = \{0.5, 0.3, 0.2\}.$$

The final risk score was scaled to a 0–100 range for interpretability:

$$R_{\text{scaled}} = R \times 100.$$

Table I presents a subset of high-risk driver samples with associated physiological and behavioural features. The risk score is, scaled to a 0–100 range. Scores below 50 indicate safer profiles, while scores above 75 denote high-risk drivers for premium adjustment and safety interventions.

TABLE I
SAMPLED DRIVER DATA WITH COMPUTED RISK SCORES

Accidents Onsite	Heart Rate	Speed	Risk Score
9	84	67	$24.99 < 50$
38	101	10	$30.58 < 50$
242	100	54	$78.08 > 75$
247	94	74	$79.16 > 75$

B. Smart Contract Design for Dynamic Premium Adjustment

To automate driver behavior–based premium adjustments, we implement a Solidity smart contract. It maintains a mapping of policyholders, each with their initial premium, adjusted premium, and a driving risk score derived from behavior data. This enables transparent, on-chain insurance policies without manual intervention, building trust and incentivizing safer driving. The design is extensible to payment handling, claims, and Purechain integration for verified incident data.

IV. PERFORMANCE EVALUATION

Using a Random Forest classifier on driving behavioural parameters, our model achieved strong multi-class performance with precision, recall, and F1-scores consistently above 0.80. As shown in Table II, Classes 1 (low risk) and 4 (critical risk) reached the highest accuracy (97.3%) and (98.15%).

TABLE II
CLASSIFICATION PERFORMANCE PER CLASS

Class	Precision	Recall	F1-score	Accuracy
1(Low risk)	0.9216	0.9495	0.9353	0.9731
2(Medium risk)	0.8837	0.7677	0.8216	0.9663
3(High risk)	0.8056	0.8788	0.8406	0.9293
4(Critical risk)	0.9200	0.9293	0.9246	0.9815

Our system performs real-time threat and risk analysis using telemetry inputs through smart contracts (Fig. 2). The evaluated driver achieved a score of 98.5/100, classified as Low Risk. Positive indicators outweighed negatives, while most other telemetry data were either neutral.

This result demonstrates the system's ability to reward safe driving and generate actionable, auditable risk feedback for insurers and policyholders. Dynamic feedback facilitates fair premium calculation and strengthens trust in automated claims and risk management. Table III compares key performance indicators between PureChain PoA^2 and Ethereum's Sepolia PoW testnet. PureChain delivers significantly higher transactions per second (TPS) and lower latency, crucial for IoV's real-time insurance needs

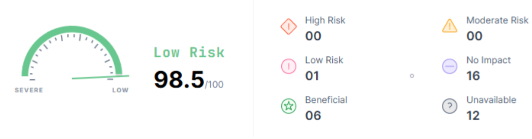

Fig. 2. Threat Score Visualization for Behavior-Based Insurance Assessment

TABLE III
PERFORMANCE COMPARISON BETWEEN PURECHAIN AND SEPOLIA

Blockchain Network	Gas Used	Transaction Cost	Execution Cost	Latency (sec)	Throughput (TPS)
PureChain	33,978	29,546	7,974	0.2	17
Sepolia	71,486	70,625	17,785	10	3.7

V. CONCLUSION

This study presents a ML-based risk analytics and streamlined blockchain framework for behavior-based IoV insurance utilising PureChain's PoA^2 consensus. Our design achieves high throughput, low latency, and secure automation of policies and claims. Future directions include integrating privacy-preserving techniques and enhancing insurance personalisation.

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REFERENCES

[1] V. Kumar, R. Ali, and P. K. Sharma, "Iov-6g+: A secure blockchain-based data collection and sharing framework for internet of vehicles in 6g-assisted environment," *Vehicular Communications*, vol. 47, p. 100783, 2024.

[2] W.-Y. Lin, K.-Y. Tai, and F. Y.-S. Lin, "A trustable and secure usage-based insurance policy auction mechanism and platform using blockchain and smart contract technologies," *Sensors*, vol. 23, no. 14, p. 6482, 2023.

[3] J. N. Njoku, C. I. Nwakanma, J.-M. Lee, and D.-S. Kim, "Enhancing security and accountability in autonomous vehicles through robust speaker identification and blockchain-based event recording," *Electronics*, vol. 12, no. 24, p. 4998, 2023.

[4] H. L. Nakayiza, L. A. C. Ahakonye, D.-S. Kim, and J. M. Lee, "Blockchain-enhanced feature engineered data falsification detection in 6g in-vehicle networks," *IEEE Internet of Things Journal*, 2025.

[5] A. Hassan, M. I. Ali, R. Ahammed, M. M. Khan, N. Alsufyani, and A. Alsufyani, "Secured insurance framework using blockchain and smart contract," *Scientific Programming*, vol. 2021, no. 1, p. 6787406, 2021.

[6] D.-S. Kim, I. S. Igboanusi, L. A. C. Ahakonye, and G. O. Anyanwu, "Proof-of-authority-and-association consensus algorithm for iot blockchain networks," in *2025 IEEE International Conference on Consumer Electronics (ICCE)*. IEEE, 2025, pp. 1–6.

[7] P. Marcillo, C. Arciniegas-Ayala, Á. L. Valdivieso Caraguay, S. Sanchez-Gordon, and M. Hernández-Álvarez, "Polidriving: A public-access driving dataset for road traffic safety analysis," *Applied Sciences*, vol. 14, no. 14, p. 6300, 2024.